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EFFECTS OF NEW APPROACH PROCEDURES ON COCKPIT DESIGN AND CHANCES FOR REALIZATION

Haeuser

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16. Abstract

Design of the cockpit as the working place for the crew and the interface between man and machine for aircraft guidance is a task of great complexity which can be structured and better mastered through the methodology of systems development. After defining the task of cockpit design, necessities are specified and the chances of using these specified values in practice in all phases of development are indicated. Examples of modifications of these specified parameters by new approach procedures are discussed.

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Introduction /1*

Along with treatment and solution of problems referring to the areas of technical utilization and flight operation procedures, the flight mechanics and infrastructure, possible advantages for the use of aircraft resulting from modified flight maneuvers, i.e., new approach procedures, require consideration of the modified requirements for aircraft handling. The crew, which bears responsibility for handling the aircraft, is confronted with a rather large variety of tasks in connection with increased flexibility of approach, shorter maneuver times and other conditions referring to sight. The aircraft systems must relieve the crew to a sufficient degree. The stress on the crew and the amount of automation of systems must be correctly measured. The interface between the crew and the aircraft systems is the cockpit. For this reason cockpit design requires special attention when new approach procedures are being introduced.

At this point in time approach procedures, necessary flight equipment, and requirements placed on the intrastructure are still the object of discussion. Therefore no complete report can be presented stating which unit must be modified for what reasons and the extent to which these modifications are technically possible. The purpose of this report is rather to express our ideas in this phase of development, and to present a total overview of the requirements for aircraft guidance by specifying suitable parameters, so that risks can be excluded early by means of analyses and experiments and so that the experience of earlier projects and individual research can be applied to the entire field.

Therefore, after a description of the task of cockpit design and the needed /2
methodology, the requirements and their characteristic parameters, including procedures for defining them, will be presented, and how the modifications are

*Numbers in the margin indicate pagination in the foreign text.

affected by new approach procedures will be discussed on the basis of the specified values.

The Task of Cockpit Design

Cockpit design and the tasks related to it, in contradistinction to the other activities of aircraft development, are defined separately and its influence on aircraft performance is judged separately. The position taken in this question is indicated below.

The design is to create a purposeful arrangement and organization of all equipment in the cockpit so that the crew can fly the aircraft safely. It includes man and his working area with the signals, service elements, voice equipment, window panes, seating arrangements, air conditioning, oxygen supply, and all other installations in the cockpit area. It analyzes the individual decisions in the area of aircraft güidance of the appropriate areas of specialization of the user and manufacturer in their effects upon cockpit design and on crew requirements. It integrates ideas from these areas of specialization within the framework of possibilities resulting from the aims for the entire project in order to solve the task of aircraft guidance in an optimum way.

Cockpit design is really a task of constructive shaping. It is affected /3 by the geometrical values of the measurements of cockpit, window panes, signals, service equipment and the need for room for an inspection and maintenance installation suitable for repairs. It considers the anthropometric values of the crew for sufficient room to move in and reaching distances permitting service without fatigue and maximally possible distances for safe reading.

However, cockpit design cannot be based only on geometric and anthropometric conditions, even if they are backed up by the interest of strength, aerodynamics, and readiness. Of equal importance for equipment integration in the cockpit, the interface between the systems and the crew, is the arrangement and organization of the equipment in accord with the capability of the crew to deal with information. Thus equipment integration is at the same time an exercise of organization of information exchange between the crew, the aircraft systems, and likewise of flight safety. The integration must guarantee that the stress on the crew does not exceed its capacity and gives sufficient support to its capability.

The requirements for aircraft guidance are determined by the extent of the tasks to be performed for it, by the time available for carrying out duties, and by the environmental conditions. The range of uses intended for the aircraft define in detail how fast and flexibly its maneuvers are to be carried out and how complex the design for the aircraft and its systems must be for this.

In cockpit design the requirements for aircraft handling, such as the flight /4 plan in navigation, surveillance and control of the flight system and steering the aircraft, are derived from this.

Both in the creation and maintenance of its prerequisites and also in their observation the task of flying an aircraft requires a definite expenditure of labor, pools, capital and time. It claims a portion of the construction burden for equipment, installation and crew. As a result of down time for the material maintenance of its systems it diminishes the operational readiness of the aircraft.

The aircraft flight capacity, the task of the crew, its responsibility and its relief by means of systems are established and all further parameters for the aircraft determined in cockpit design. The question arises as to how far the value of experience from earlier developments can be applied and how the special means for increased capacity can be considered.

Requirements of Cockpit Design and Their Specification /5

It is desirable to limit individual developmental tasks, i.e., development of equipment for the flight control system, to an early stage in the project in order to be able to begin the work purposefully and promptly. However, the limits of the groups of tasks must be specified. The cockpit developer has the task of working out the requirements for the individual tasks and, as indicated in the previous chapter, to integrate the possible solutions of the individual areas of specialization for an optimum total solution. Among other things it is necessary to determine what additional labor can be spent by the crew for flight control in addition to their tasks regarding the flight safety and supervision of the proper function of the aircraft systems during approach.

Cockpit design is a complex totality of effort which has been difficult to structure up to now. The problem actually consists in breaking it down into individual, manageable steps which can be treated in isolation and whose results can be integrated as components into the total plan. Another difficulty is found in the use of anthropotechnical methods of evaluating performance in the early stage of development. The reasons for this lie in the complex intricacy of the task, particularly in the fact that the functions of aircraft guidance are realized both through the performance of the crew and partially by means of technical systems. Such complex relationships are managed better through the methodology of system development, Systems Engineering. For cockpit development this must be consciously and formally applied.

The first step in system development is the specification of the cockpit /6
or of the aircraft guidance which is then realized by means of suitable cockpit design. The effects of the new approach procedures must be given consideration along with the aircraft data and the necessary infrastructure in the cockpit specification. However, up to now only "descriptive specifications" had been recognized for cockpit design, not those in which the requirements for aircraft guidance are predominantly solved by concrete realization, so that different solutions could be compared and improvements, perhaps by means of new approach procedures, measured. This fact alone characterizes the situation of systems development in this area. The description of realization must be replaced by parameters characterizing it. In all phases of aircraft development the specified parameters should be able to be judged, computed or measured. On the one hand they must be derived from the performance data of the aircraft and on the other must represent the contribution of aircraft guidance to the capability of the aircraft.

Table 1 provides a representation of such goals for the evaluation of the function of airplane guidance in reference to the aircraft requirements.

For the airplane the new approach procedures aim particularly at increasing /8
transportation ability by avoiding operational limitations and by improving flexibility of use by increased use of possible airports. The performance necessary for this is provided by the aircraft guidance, i.e., propulsion and ascension control of the aircraft or picking up information through the external field of vision either. The other parameters characterize the cost necessary for aircraft guidance.

TABLE 1.

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Presentation of goals for aircraft development
(Basis for the cockpit specification)

Transport performance:
Mean operational speed

Time out of service caused by limitations such as weather conditions, capacity of controlled space, necessary ground time (fueling up, flight plans, etc.)

Useful load/Useful volume

Structural weight/Space requirements

Availability

Material maintenance time

Flexibility of Use

Multiplicity of tasks

Intrastructure usefulness and independence

Suitability of airports, presence of special navigational equipment

Capability of operational execution

Weather conditions, noise abatement

Safety

Stress on crew

Costs

For the evaluation of the capability of the aircraft and of aircraft guidance in covering operational limitations and inadequacies of the infrastructure no standard methods have yet been developed, but instead models which simulate the concrete service of the user are analyzed. Suitable indicators of crew stress are lacking, although the analyses of work and of working methods of the owners, pilot associations, systems firms and anthropotechnical research constantly reduce the gap between simplifications which are too general and knowledge which cannot be applied to development. All other magnitudes can be better predicted and controlled, and experience is available from the development of other systems.

Table 2 has been derived from Table 1 and is an approximation of a suitable specification framework for aircraft guidance. The parameters of the aircraft guidance function and their realization have been divided in such a way that it is possible to separate the functional capabilities and the expense for realization and for the necessary prerequisites.

TABLE 2. SPECIFICATION FRAMEWORK FOR AIRCRAFT GUIDANCE (FUNDAMENTALS FOR COCKPIT SPECIFICATION) /9

Function	Capability Parameters	Parameters of Prerequisite/Expense
Flight planning and control	Range	Weight
Execution and standard magnitudes	Precision	Material maintenance time
Flight steering	Time consumption	Crew activity
Regulated quantities	Safety in execution function	Operating period of guidance
Onboard systems operation	Possible operational conditions	Supply
Decision regarding execution	Possible measures	Costs
		Requirements of intra-structure/flying room, navigation and communication equipment
		Necessary time out of service
		Criteria for flight/execution, weather, noise

The following section provides quantitative values or outlines the possibility of obtaining them. The data can be partially referred to aircraft projects already realized. The performance parameters according to Table 2 must be determined in many cases by testing the bases of existing regulations and through experimental programs. /10

Parameters for Cockpit Design and Modification by New Approach Procedures

The specification outline given in Table 2 was to be used to compare quantitative testing of cockpit design in various existing aircraft. Such a procedure is already common for the entire aircraft, but has been used up to now only for a few individual parameters in important subsystems, such as flight guidance. It is expected that visualizing these parameters of partial systems and partial functions will facilitate the comparison, so often difficult today, of various concepts and equipment, and will make possible a purposeful and thus effective improvement. This takes place primarily by having the specification aimed at the complete scope of the parameters and working out their share of the entire project.

The above division of the aircraft guidance function requires discussion. /11
It forms a literal compromise between the common description of activity for the crew of a transport plane and a limitation according to speech usage in regulatory technology. Figure 1 gives the definition where flight planning and control provide guidance and normal magnitudes, and flight steering provides the regulated quantity.

One example of specification of flight guidance performance is the ability of the crew to optically identify the landing point of the airplane as an extension of the flight trajectory and to correct the flight trajectory correspondingly. This capacity is guaranteed by the external range of vision. At a 2.5° angle between guide and approach the FAA ground visibility angle permits this task to be carried out without ground equipment by means of the "blur effect" of the ground structure before the landing point. Figure 2 shows this principle. A sharp inclination of the descent path reduces this effect and results in larger necessary ground visibility angles or additional landing path markings. Narrow structural limits are placed on any enlargement of the external field of vision of the crew, such as by narrowing the distance between the size and the front panes or by reducing the structural height of the instrument panel.

A further example of performance parameters are given by the possible operational conditions and the possible measures for flight guidance. Figure 3 shows the range of tasks which are to be handled by the crew in a conventional /15
transport aircraft in approach, and shows the distribution to the various functions. The amount of time necessary to carry out the tasks completes the performance data. These characteristics are provided by the analysis of time required.

The modification in capability immediately finds its reflection in the parameters of expenditure according to Table 2. The ratio of aircraft guidance to structural weight is absolutely and relatively high, even when advanced technology exercises a strong influence here. This parameter is usually determined ahead of time and controlled in all developmental phases of aircraft construction. Here the main structural groups are added to the individual items in the parts list. So far a functional arrangement of weight, illustrating the expense for realizing a function, has not been found. Figure 4 shows the ratio of weight of the aircraft guidance function to total weight. This magnitude is particularly worthy of note when it is compared with the useful load or the cost for transporting this weight. This weight ratio is to a large extent determined by decisions about cockpit design.

Reduction in the theoretically possible transportation performance of the total aircraft because of uncertain time for inspection, maintenance and repair is represented by the curve in Figure 5. This is somewhat higher for civilian owners because of greater uniformity in using their aircraft. A large amount of flight guidance is a result of the amount of debugging time (Figure 6). Worthy of note in this example is the number of various navigation devices which are provided to increase service flexibility.

Increasing flexibility by new approach procedures can lead to a further rise in material maintenance time if the frequency of down time and time for inspection, maintenance and debugging does not remain correspondingly short. /19

The down time frequency of the system, i.e., their reliability, determine the safety of the functional capacity of the devices. Up to now such computations have been carried out to demonstrate sufficient down time safety, e.g., for autopilots in automatic landing. The number of safe landings must reach a definite minimum value. In an analysis of safety cockpit design determines this minimum value and the possibility of successful takeover of the function by crew performance after failure of technical equipment.

It is in just this phase of approach that the crew has a large job to carry out. While Figure 3 reflects only the number of jobs, analysis of working time and working methods can provide further quantitative values of crew work. Here stress, i.e., in the simplest case the ratio of required to available time, is

in all conceivable cases of flight guidance a limit which must not be exceeded in the interest of flight safety. Further refinement of the determination of the range of crew activity and the stress related to it can be determined experimentally and through test flights. Reduction of the time available for carrying out the task without a concomitant increase in stress for the crew can be achieved by better adaptation of instrumentation and by automation of crew /20
functions. Here economic limits are set upon the degree of automation.

The costs of the aircraft guidance function are most comparable when the direct operating costs can be used. In addition to the number of crew members, procurement and material maintenance costs have predominant influence. The share of aircraft guidance applicable to procurement costs can be specified, determined and controlled analogously to weight determination. Permissible additional expenditure closes the circle of consideration. The possible advantages occasioned by the near approach procedures in the situation existing at the time of their introduction are limited by the price to be paid for them.

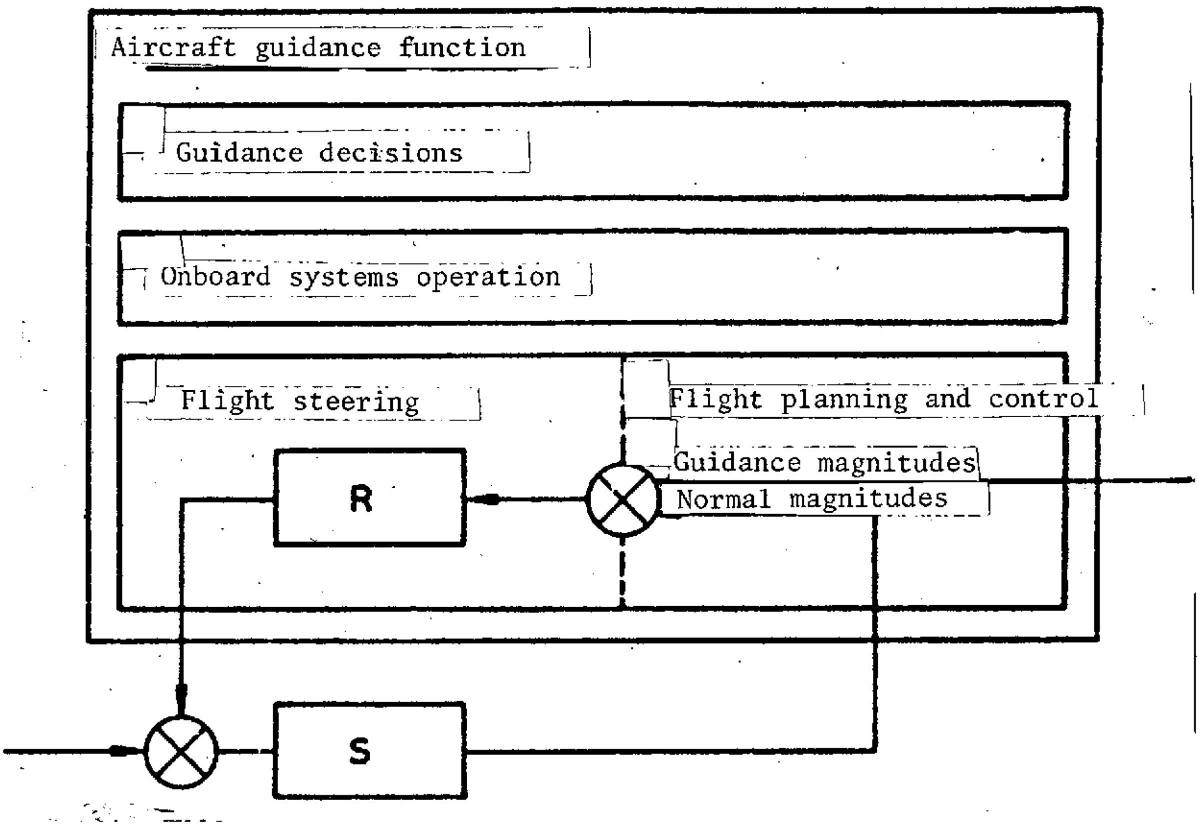

Figure 1. Explanation of Concepts. /12

Parameters

θ = glidepath angle
γ = inclination of central part of aircraft
β = angle of vision
v = angle of blur

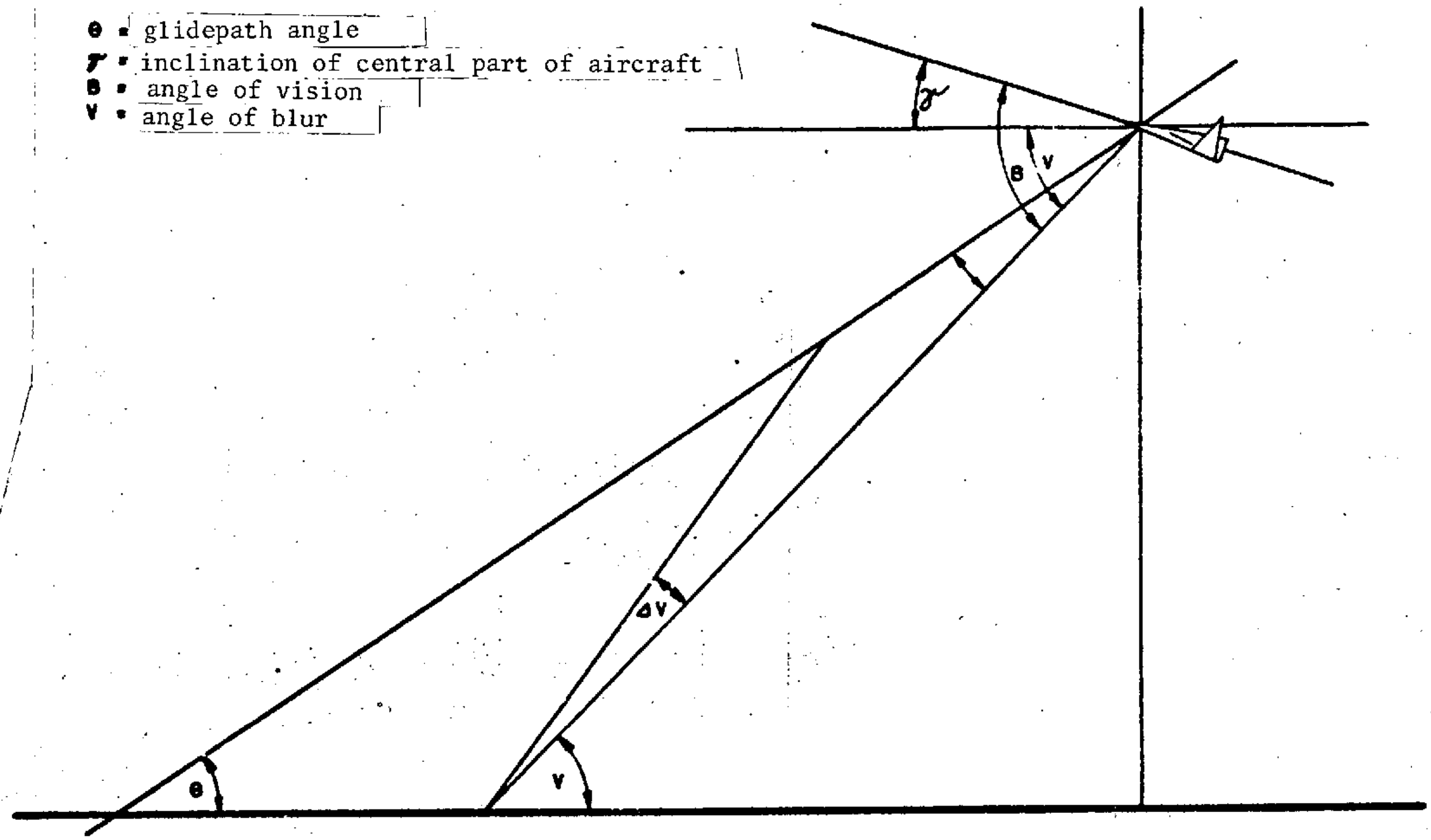

Figure 2. Ground Visibility Conditions in the Direction of Flight. /13

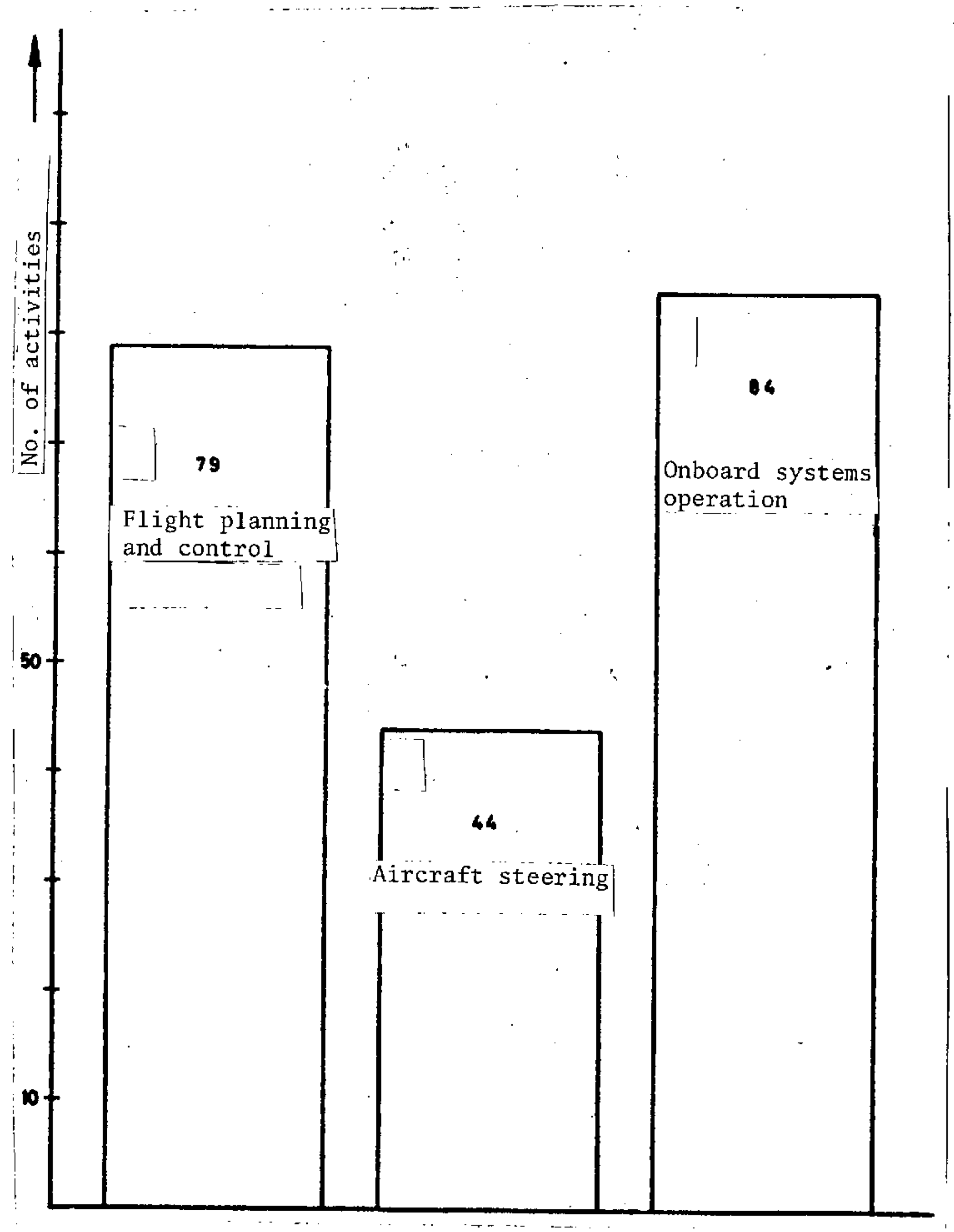

Figure 3. Work Analysis of Landing Approach. /14

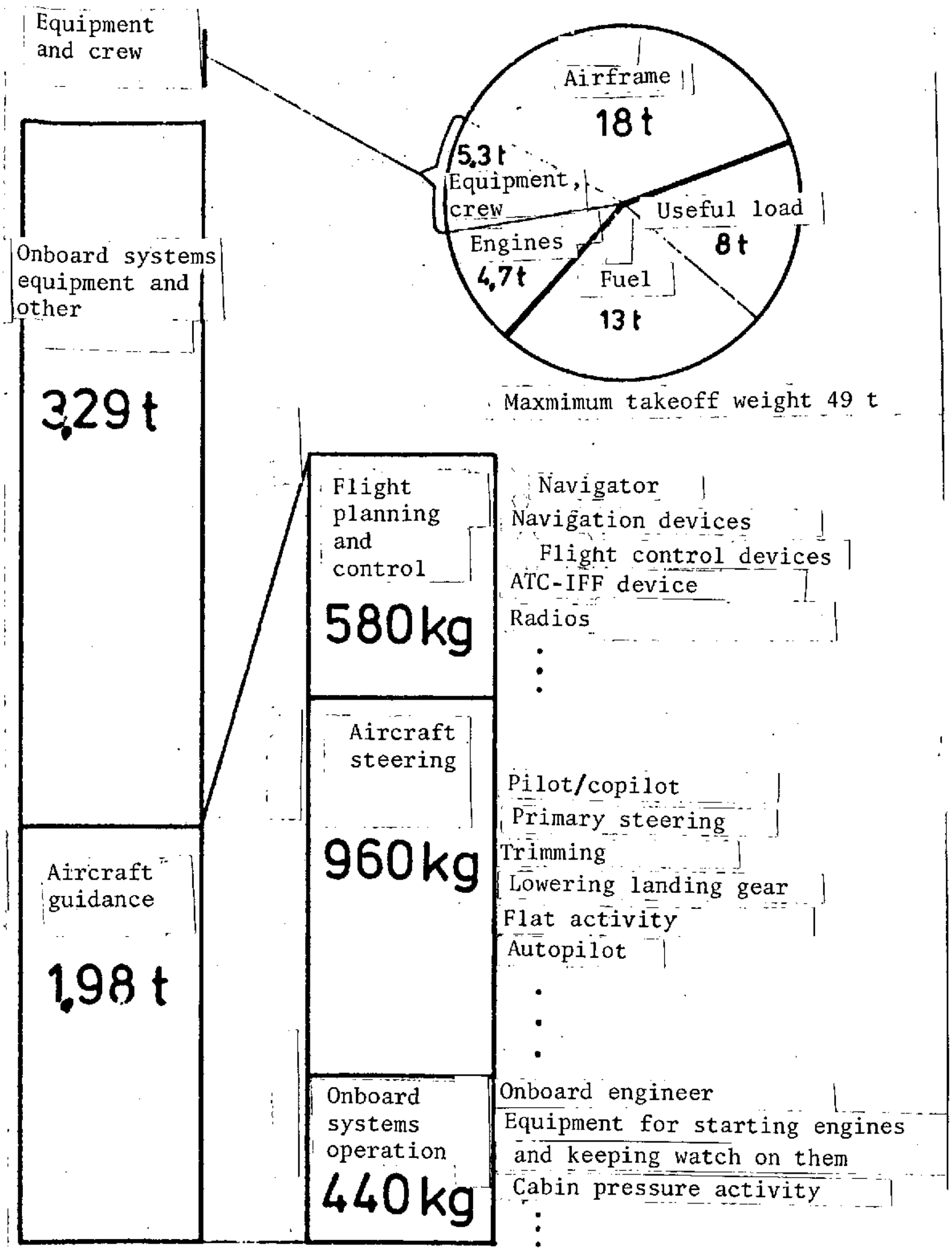

Figure 4. Weight Share of Aircraft Guidance. /16

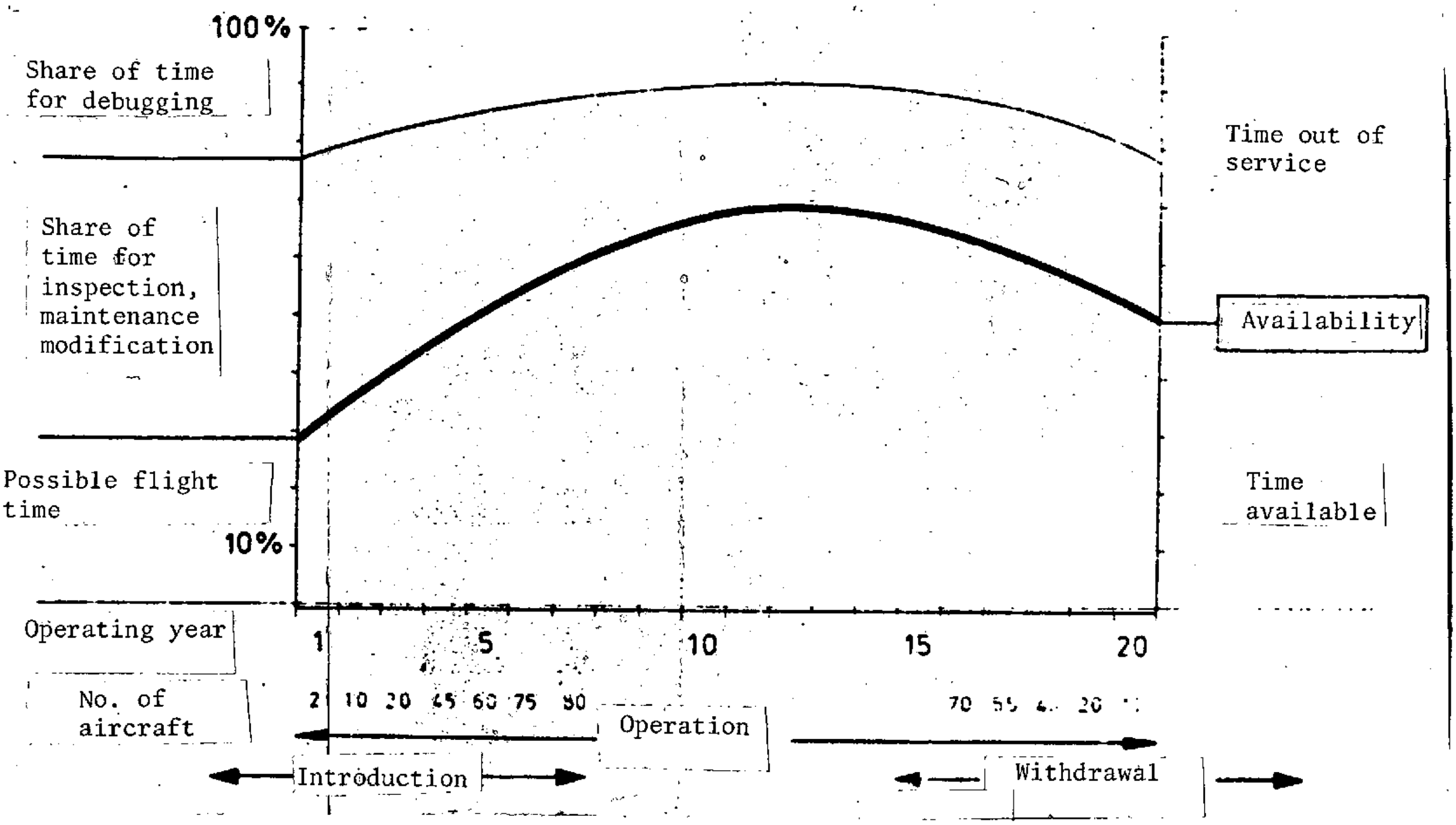

Figure 5. Development of the Availability of an Aircraft Project (Schematic). /17

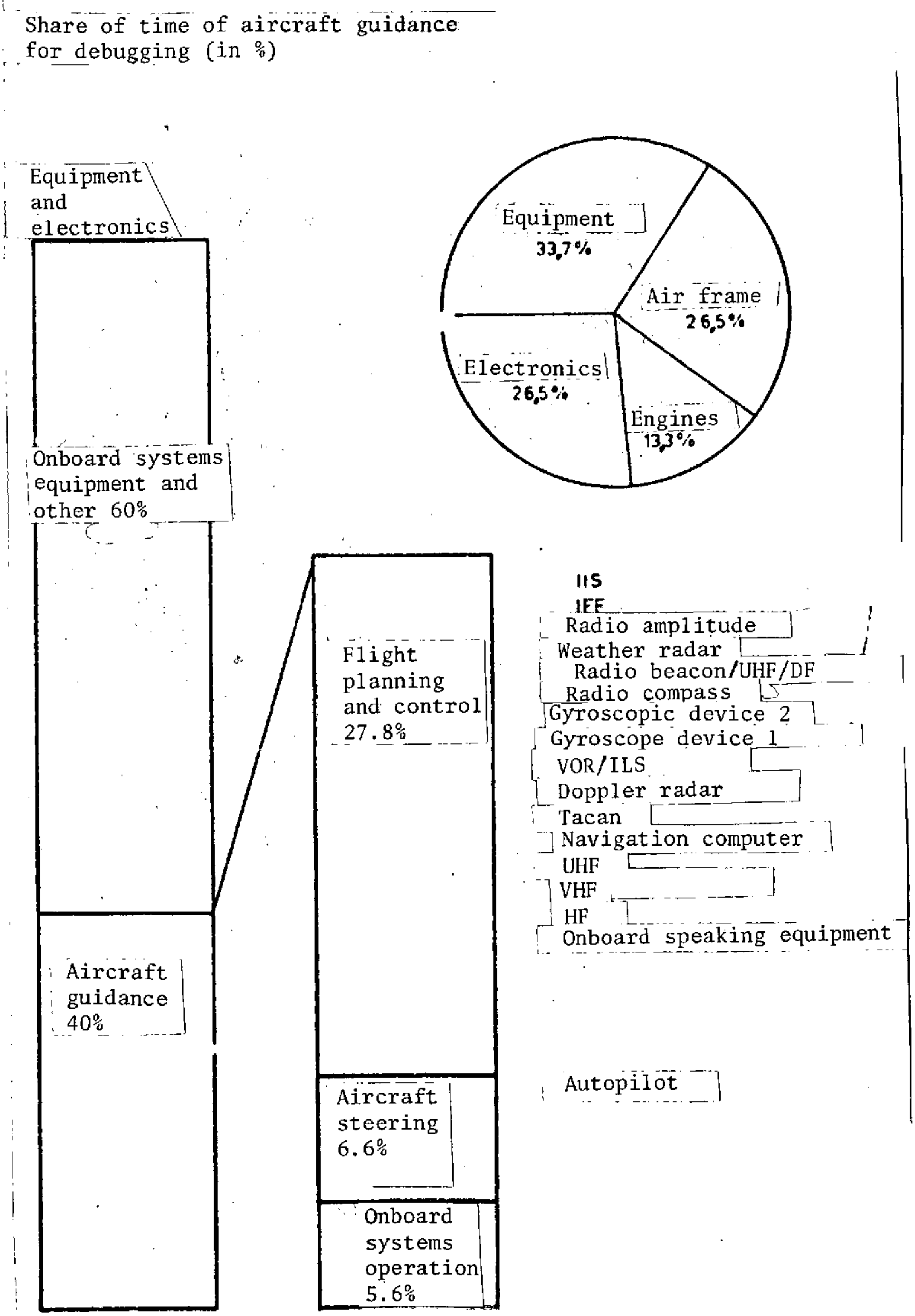

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Figure 6. Equipment for Starting Engines and Watching Over Them.

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